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Effectiveness of a Virtual Laboratory to Develop the Skills of Identifying Fiber Type Using Chemical Methods

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***Abstract*— Virtual reality is an information technology innovation that creates a 3D simulated environment to assist individuals to easily deal with and visually perceive information. It has been utilized in multiple domains; however, it is noticed that it has rarely been used in the field of clothing and textiles, despite universities' dire need to provide alternatives to traditional laboratories. This study aims to design a proposed virtual laboratory that provides students with the skill of identifying types of fibers using chemical methods, and eventually measure its effectiveness to keep pace with the swift technological development to employ it in the educational process. The study adopts an experimental-design quantitative approach and uses the achievement test, observation card, and trend scale to verify the study's hypotheses after applying them to a representative sample of textile chemistry students in the department of Fashion and Textiles, King Abdulaziz University, Saudi Arabia. According to the result of the achievement (T) test of the interconnected samples, the results indicated that there are statistically significant differences between the mean scores of students for the (pre- and post) achievement test in favor of the post-test. Research sample tends to be positively oriented towards learning via the proposed virtual laboratory. The researchers recommend using virtual laboratories to support traditional laboratories in teaching the skill of identifying types of fibers using chemical methods.**

Keywords— Virtual laboratory, Textile, Fiber, Identification, Textile Chemistry.

I. INTRODUCTION

Spread of technological revolution and information technology is an indication of the modern era; the world has become well-connected like a small village, making the need to benefit from this revolution in the educational process inevitable. Modern technology helps to face many difficulties of the educational process, such as abundance of information, increase of number of students and transportation to educational institutions. E-learning is a key development instrument in the evolution of educational processes [1], which is one of the modern teaching methods in delivering information to the learner in the shortest time, least amount of effort and greatest benefit using computers, networks, and multimedia [2]. More recently, e-learning has received greater attention as many studies and research on e-learning and distance education initiatives have been published and have become available for various educational institutions. This resulted in the emergence of modern educational formulas such as virtual reality-based education [3]. Virtual reality is a three-dimensional virtual environment which assimilates reality that is electronically formed and depends on the transfer of human consciousness to this environment so that the person dives into imagination away from the physical place. Human senses are also a part of this environment using several tools such as the helmet, which a user can experience and deal with within educational virtual environments, making human senses an essential step to modernize education [3], [4]. Flexibility and adaptation to different educational objectives are key advantages of using the virtual environment, making it a contribution to meeting educational and training needs while taking into consideration the needs of trainees [5]. Several disciplines have used virtual reality, including but not limited to science, chemistry, medicine, and aviation. The field of clothing and textile has had its share in using virtual reality; nevertheless, it is observed that virtual reality was not used in virtual laboratories that aimed to develop the skills of identifying the type of fibers through chemical methods. Although, there has always been a dire need for this technology, especially when switching to distance education, as was the case with the COVID-19 pandemic. This outlines the problem which shall be undertaken in current research, which aims to design a proposed virtual laboratory for learning the skills of identifying the type of fibers using chemical methods and duly measuring its effectiveness by verifying the following hypotheses:

1. There are statistically significant differences between the mean scores of the students for the (pre- and post-) achievement test in favor of the post-test.
2. Students tend to be positively oriented towards learning the skills of identifying the type of fibers through chemical methods using the proposed virtual laboratory.

II. Review of Literature

Virtual reality is a computer-based learning tool in which multimedia can be used to create a three-dimensional environment that reflects real-life situations and works to harmonize the learner with this environment. The learner could interact with it by providing synthetic reactions to one or more senses; this gives a feeling of integration and/or presence within the simulation [6], [7]. Virtual reality has many features such as interactivity, engagement, participation, simulation, navigation, and telepresence. It has also been used in several domains, including medical, design, engineering, entertainment, and education fields [8]. The unique advantages of simulations provide a cheap and easy way to educate students by giving them real life experience that enhances their self-efficacy and interests, as well as giving them the opportunity to attempt many career paths such as medicine, aviation, and engineering, among others [9], [10]. Education is one of the fields that have witnessed great developments in the use of virtual reality, in which an entertaining and enjoyable learning environment is created and supplemented with exploration and fun. This leads to an increase in the level of student achievement and motivation [11], [12]. As perceived by the researchers, although virtual reality is one of the most exciting innovations created to support the educational process, its main objective should have been to support traditional classroom-based learning and to use it in distance training rather than replacing it [12], [13]. One of the most important advantages of virtual reality in education is that it creates an attractive and safe learning environment that contains fun, entertainment, and information. In addition, it could be used as an alternative to real experiences that are difficult to apply such as low-temperature environments. Virtual reality also improves the student's skill so that a student can use it by itself to carry out and repeat infinitely experiments without time restrictions due to its limited components and ease of control. Benefits of virtual reality are evident when compensating for students who miss attending traditional laboratories, which helps them continue the educational process [5], [8], [9], [14], [18].

Virtual laboratories are one of the key virtual environments that have been designed and studied by researchers to support the educational process in various fields such as medicine, chemistry, physics, engineering, and clothing and textiles. Studies have proven the effectiveness of these virtual laboratories and their positive impact on students' educational achievement, recommending conducting more studies on such laboratories in various fields to benefit from their advantages [11], [18],[29]. The virtual laboratory is seen as an electronic simile, or rather a metaphor, of the real laboratory [30]. It has a similar efficacy to it, and therefore it can be used as a supplement rather than a substitute, except in the narrowest of cases, such as emergency situations when experiments cannot be conducted for reasons such as distance education, lack of laboratories and kits, insufficient materials, and the risk of chemical reactions [10], [11], [18], [21], [24], [28]. Virtual laboratories help increase students' focus on the experiment rather than on materials and equipment. They also provide opportunities to explore phenomena that cannot be tested in a traditional laboratory, in addition to simulating extreme conditions such as changing gravity or high temperature, which would be expensive or impossible to perform in a traditional laboratory. Another significant advantage of virtual laboratories is that its material cost is lower than the traditional one because there are no physical devices in the virtual domain, making it possible to provide hazardous and/or expensive devices that are difficult to provide in a conventional laboratory [17], [23], [27], [28], [31], [33]. Therefore, it can be said that the cost of setting up a science lab that is used only for science lessons is higher than the cost of setting up a computer lab that can be used for many lessons [11].

A. *Textile chemistry course*

The skills of identifying the type of fibers using chemical methods are taught in the textile chemistry course, which is one of the core courses in the Department of Fashion and Textiles. In this course, students learn about fibers and their chemical and biological properties, in addition to the different methods of identifying their types. The course usually contains a practical part in which various experiments are performed in a traditional textile chemistry lab. Course teachers usually face some challenges that may not allow all students to participate in the experiments, such as the lack of equipment, kits and materials used in the experiments, or some safety problems that may arise due to the students' misuse of dangerous chemicals. The researchers also noted that after easing the precautions against the COVID-19 pandemic, and the return of in-attendance education while maintaining social distancing and continuous sterilization with alcohol solutions, course teachers were unable to conduct experiments that depend on the use of flames, fearing of igniting a fire due to the existence of alcohol on surfaces.

This research seeks to keep pace with up-to-date technological developments and fill potential gaps that may result from the challenges of pursuing the educational process in emergency situations, such as the need to switch to distance education as was the case with the COVID-19 pandemic, and the lack of traditional laboratories in emerging universities. This can be achieved by designing a virtual laboratory to develop the skill of identifying fiber types using chemical methods and eventually measuring its effectiveness. The virtual laboratory also contributes to maintaining the safety of students from the risks that they may face in a traditional laboratory.

III. METHODOLOGY

This research adopts the quantitative approach, an approach used to examine the validity of theories through studying the relationship between quantitatively predetermined variables using a standardized measurement tool so that it results in numerical data that can be analyzed statistically [34]. Determining the approach to be followed in this study, this research adopts the experimental design to study a single group, which examines the effect of an independent variable on a dependent variable of this group. This design includes a pre-test that measures the dependent variable, then the sample is exposed to the independent variable. This step is followed by a post-test that measures the effect of the independent variable on the dependent variable itself [34]. The independent (experimental) variable is the variable that the study aims to measure its impact on the situation (learning using the proposed virtual laboratory) [35]. The dependent variable is the variable that is affected by the change of the independent variable; it is the variable that the study aims to measure (the skill of identifying the type of natural fibers using chemical methods) [35].

The research sample was selected on a one-group basis so that the same selected group is subjected to a pre-test to identify their status, and then subjected to the experimental variable. The next step is to conduct a post-test so the difference in the results of the group is due to the influence of the experimental variable [36]. Subjects of the experiment are all the students who were in their fifth level and enrolled in the Textile Chemistry course (FT342) in the second semester 2019/20. They were (10) female students from the Department of Fashion and Textiles, Faculty of

Human Sciences and Design, King Abdulaziz University in Jeddah, Saudi Arabia.

Three research tools were used during the application of the experiment to verify the hypotheses of this study, namely an achievement (pre-test and post-test), an observation card, and a trend scale to measure the students' tendency towards learning the skill of identifying the type of fibers using chemical methods in the proposed virtual laboratory.

IV. PROCEDURAL STEPS FOR SETTING UP AND DESIGNING A VIRTUAL LABORATORY

This study adopted in designing the proposed lab Abdullatif Al-Jazzar model (2013) due to the relative modernity of the model, which aims at serving e-learning and distance education. The model comprises of five main stages:

A. Analysis stage

At this stage, the characteristics of the target learners were analyzed. In this study, the target learners are all fifth-level students who are enrolled in the Textile Chemistry course (FT342) for the first time, and their ages range between 20-22.

During this stage, the general learning objectives and e-learning content were identified based on the approved textile chemistry course description. The aim of the proposed virtual laboratory was for the student to master the skill of identifying the type of fibers using chemical methods. The aim of the fiber’s combustion experiment is that the students identify the type of fabric by knowing the properties of the fibers during burning. The general objective of the microscopic examination experiment is for the student to identify the type of fabric through the longitudinal and transverse sections of the fibers. The general objective of the dry distillation experiment is that the students identify the type of fabric by knowing the type of vapors emitted during the experiment.

B. Design stage

The educational content was organized according to the topic sequence for the Textile Chemistry course (FT342). Therefore, the selected lessons are fiber’s combustion, microscopic examination, and dry distillation experiment, respectively. Experiments were conducted on four different fabrics (cotton, wool, silk, and polyester) due to the diversity of their fiber properties and frequent uses in similar courses. The allocated times of the lessons were two hours for the fiber’s combustion, and 90 minutes for the microscopic examination and the dry distillation. The cognitive objectives for each lesson were identified. In the fiber’s combustion, the student should be able to identify the tools used in it, distinguish the characteristics of the different fabrics (cotton, wool, silk, and polyester), and classify the type of fabric during the combustion process. In the microscopic examination, the student should be able to identify the tools used in it, distinguish the characteristics of the longitudinal and transverse sectors of different fabrics (cotton, wool, silk, and polyester), and classify them. In the dry distillation, the student should be able to identify the tools used in it, distinguish the type of vapors emitted using sunflower detectors for different fabrics (cotton, wool, silk, and polyester), and classify them. Self-learning strategy was used during the lessons using the computer, virtual reality software programs, virtual reality tools (virtual reality glasses and controllers), and (pre- and post) achievement tests to measure the students' educational achievements.

C. Production stage

The virtual lab was set up and designed in the (e-learning innovations lab) of the Deanship of E-Learning and Distance Education at King Abdulaziz University, and it covers all the previously mentioned topics using several programs: (Unity, Blender, PowerPoint, After Effects, Microsoft Expression Encoder 4 Screen Capture). The following shapes illustrate some images of the proposed virtual lab prototype:

Fig. 1. The main menu appearing when the proposed virtual lab is launched

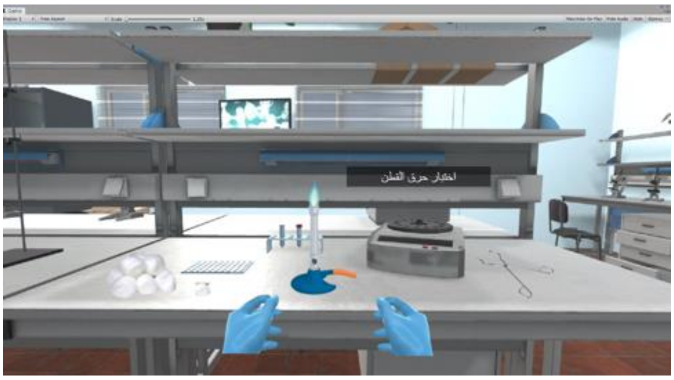

Fig. 2. First experiment interface: fiber's Combustion

Fig. 3. Second experiment interface: Microscopic Examination

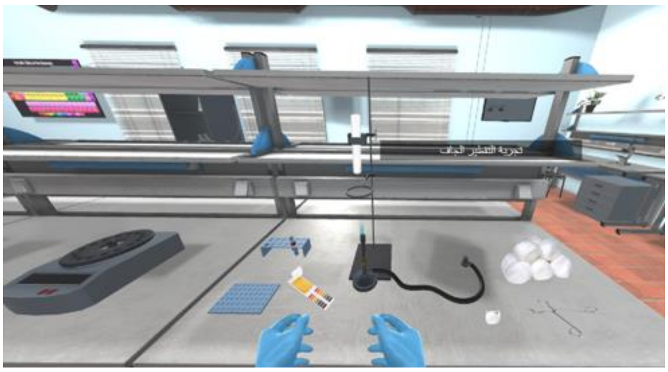

Fig. 4. Third experiment interface: Dry Distillation

D. Assessment stage

At this stage, the prototype of the proposed virtual laboratory was modified and developed, considering the educational content. Few modifications were introduced such as changing its name from chemical textile lab to a simulator, changing the time dedicated for the combustion experiment, which proved to be very fast in the prototype, and finally placing colored pieces to indicate the fabrics due to the difficulty of simulating it in the virtual lab.

E. Implementation stage

To verify the validity, the proposed virtual laboratory along with its tools were applied to the experimental research sample. The experiment continued over a period of two weeks, as it was conducted on one day only every week for three hours. This stage included the following main steps:

1) Pre-application of the tools

The pre-achievement test was applied on the first day of the experiment to measure the level of educational achievement of the students before conducting the experiments on the proposed virtual laboratory. The students were asked to answer all the questions. This was followed by introducing the students to the virtual reality glasses and controllers, which are the tools used in the proposed virtual laboratory with an explanation of how they function. Finally, the scenarios of the experiments in the proposed virtual laboratory were explained, as illustrated in Figure (5).

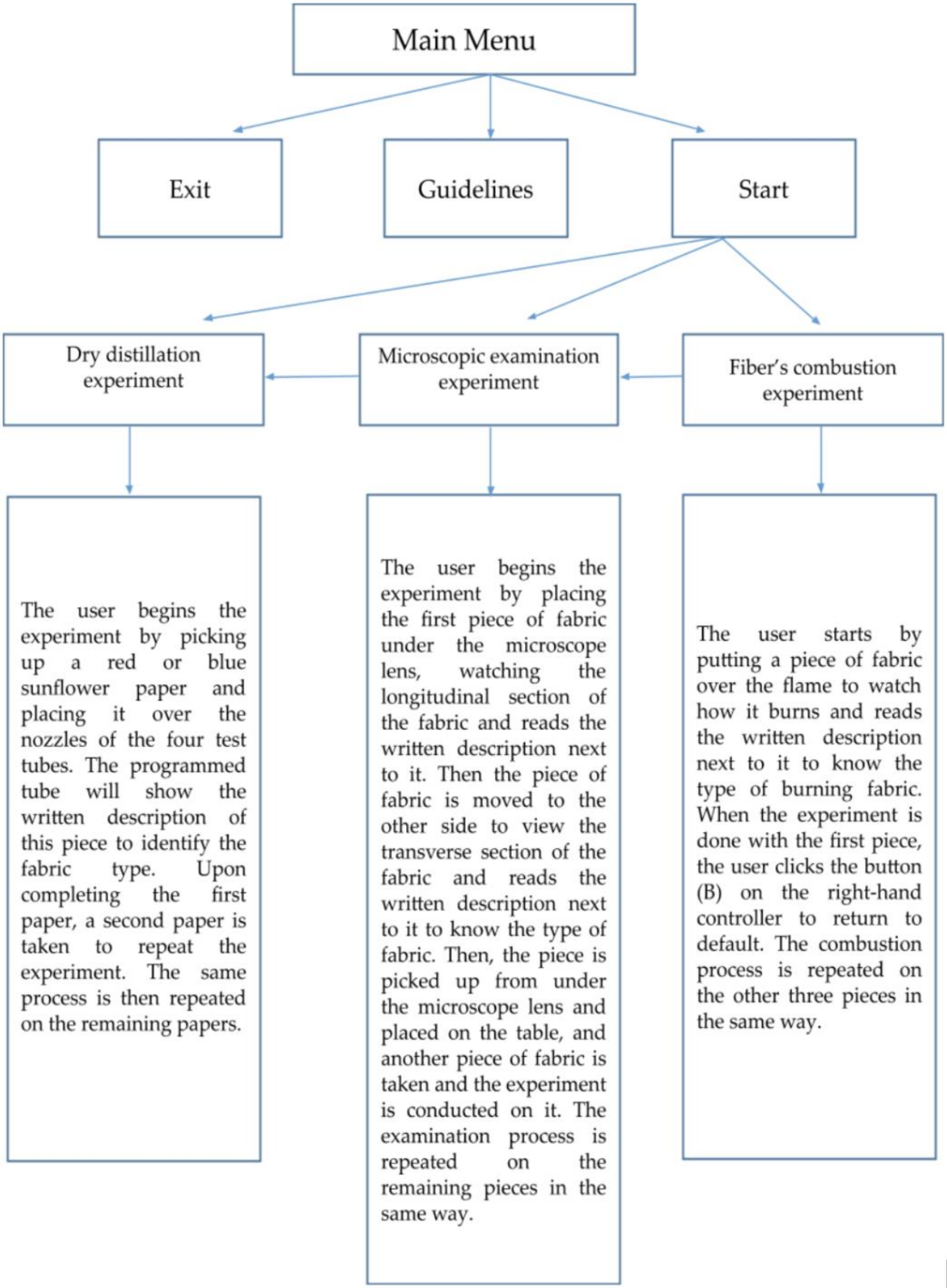

Fig. 5. Scenarios of the experiments in the proposed virtual laboratory

2) Application of experiments in the proposed virtual laboratory

The fiber's combustion experiment was applied on the first day by the research sample, and it lasted for two hours as the students lacked adequate experience in dealing with virtual laboratories. In the second week, the microscopic examination and dry distillation experiments were conducted by research sample. Each experiment lasted for 90 minutes during which students were supported by continuous follow-up and finding quick remedial solutions to any emerging problems, such as physical obstacles, i.e., equipment failure, or technical problems. This aimed at feedback-based continuous development. The following shape illustrate how the proposed virtual laboratory looks like, with an explanation of each of the experiments.

Fig. 6. Main menu displayed for students in the virtual lab

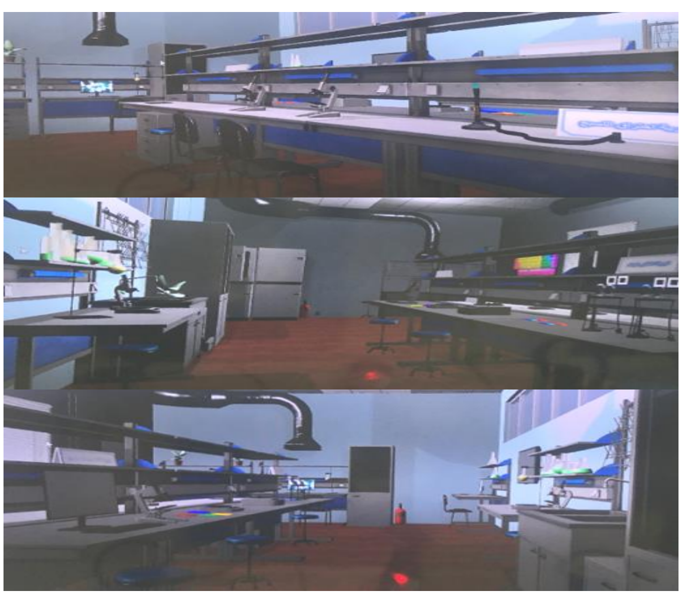

Fig. 7. Different interfaces of the virtual lab

The textile combustion experiment started with holding a piece of fabric using forceps and exposes it to the flame, while observing the combustion process, and reading the displayed written description of the method of combustion and the emitting odors. The student can differentiate between the different fabrics because the manifestations of the burning process differ according to the types of fabrics in terms of their ignition, liquefaction, flame shape, odor, and combustion residues.

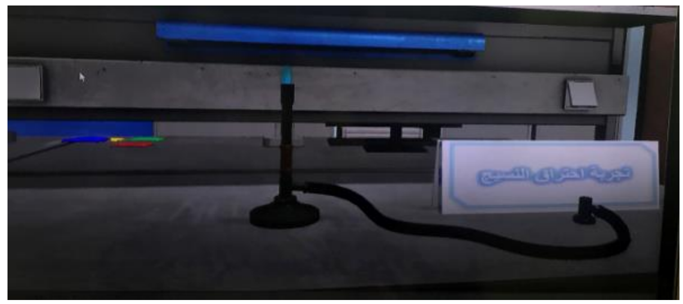

Fig. 8. Interface of the fiber's combustion experiment

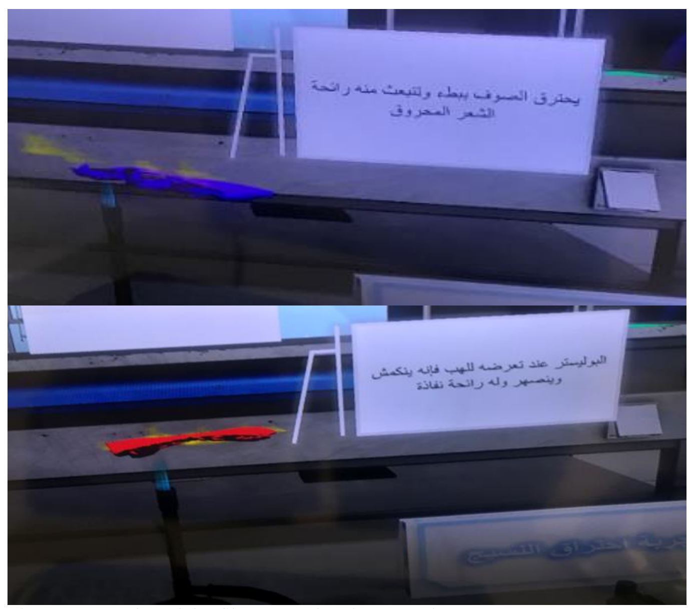

Fig. 9. Examples of the fiber's combustion experiment

In the microscopic examination experiment, the student holds a piece of fabric using forceps and puts it under the lens of the microscope, while observing the images that appear on the computer screen of the longitudinal and transverse sections, and then the student reads the displayed written description of the shape of the sector.

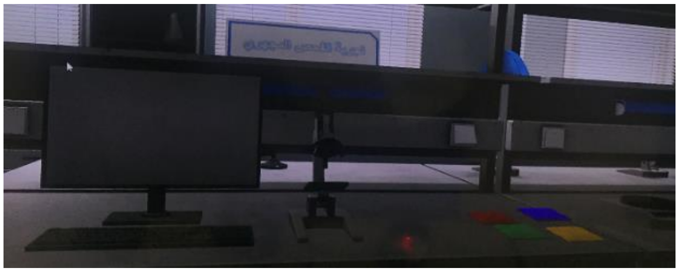

Fig. 10. Interface of the microscopic examination experiment

Fig. 11. Examples of the microscopic examination experiment

The third experiment is the dry distillation experiment where the fabric sample is placed in a test tube and exposed to a flame for heating. The student holds the sunflower paper using forceps and exposes it to the vapors emitting from the tube, while observing the change in color of the paper. Meanwhile, the student reads the displayed written description to explain the reason for the color change and the type of fabric.

Fig. 12. Interface of the dry distillation experiment

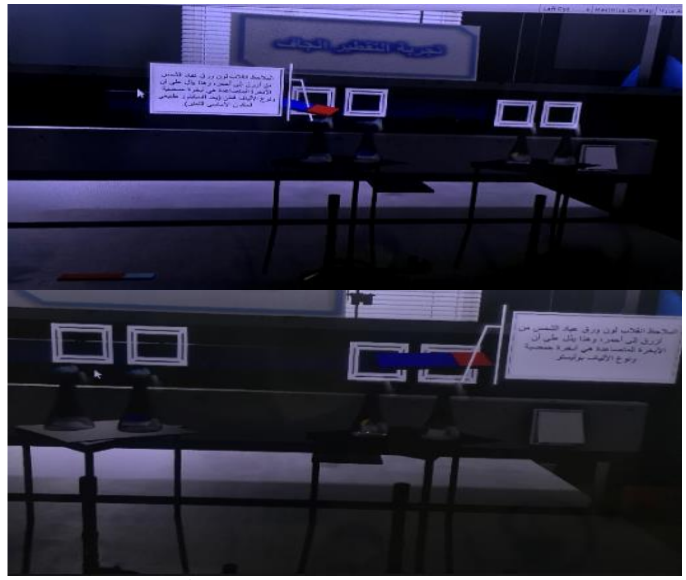

Fig. 13. Examples of the dry distillation experiment

3): post-application of the tools

After the completion of the experiments, the post-test for the achievement test and the students' attitude scale were conducted.

V. Results

The Shapiro-Wilk test was conducted to find out the nature of the data and to determine the appropriate statistical test for such data. Test results are as shown in Table (I):

TABLE I: Moderation test

	Shapiro-Wilk Test Value	Freedom Degrees	Indication Level
Pre-test	0.862	10	0.080
Post-test	0.872	10	0.105

From table I, it is evident that statistical significance for each of the total scores of the pre-test and post-test is higher than the level of statistical significance (0.05), which indicates that the data follow a normal distribution and therefore it is possible to use a (T) test for the dependent (correlated) samples.

A. Validation of the first hypothesis

To verify the validity of the first hypothesis which states: “There are statistically significant differences between the mean scores of the students for (pre- and post-) achievement test in favor of the post-test”, the achievement test was applied to the experimental research sample before and after using the virtual laboratory.

The (T) test was applied to the dependent (correlated) samples for the differences between the mean scores of the (pre- and post-) achievement test. Results of the (T) test are illustrated in Table (II). It is evident from table (II) that the statistical significance of the calculated value of the (T) test is less than the level of statistical significance used, which is (0.05). This indicates that there are statistically significant differences between the scores of the students in the (pre- and post) achievement test in favor of the post-achievement test.

To identify the size of the proposed virtual laboratory effect, the Eta square equation was applied:

$$n^2 = \frac{t^2}{t^2 + 2(n-1)} = 0.49$$

t = value of (t) = 4.191, n = number of experimental sample = 10.

It is also found that $n^2 = 0.49$, which indicates that the proposed virtual laboratory has a significant effect.

B. *Validation of the second hypothesis*

To verify the validity of the second hypothesis which states: “Students tend to positively oriented towards learning the skills of identifying the type of fibers through chemical methods using the proposed virtual laboratory”, descriptive analysis was used to analyze the results of the students' attitude towards the proposed virtual laboratory by computing the frequencies, ratios, mean and standard deviation of the sample responses, compared to the estimated balance of the five-point Likert scale as illustrated in Table (III), and the results were shown in Table (IV).

TABLE II: RESULT OF THE (T) TEST OF THE CORRELATED SAMPLES FOR THE DIFFERENCES BETWEEN THE AVERAGE SCORES OF THE (PRE- AND POST-) ACHIEVEMENT TEST

Achievement Test		Sample Volume	Arithmetic average	Standard deviation	Calculated value of (T) Test	degrees of freedom	Significance level	Statistical Significance
	Pre-	10	7.3	2.83	4.19	9	0.002	In favor of post-test
	Post-	10	11.9	2.68				

TABLE III: ESTIMATED BALANCE ACCORDING TO THE FIVE-POINT LIKERT SCALE

Likert scale	Weighted average	Period	Response
٥	٤,٢٠ – ٥,٠٠	٠,٨٠	Strongly Agree
٤	٣,٤٠ – ٤,١٩	٠,٧٩	Agree
٣	٢,٦٠ – ٣,٣٩	٠,٧٩	Neutral
٢	١,٨٠ – ٢,٥٩	٠,٧٩	Disagree
١	١,٠٠ – ١,٧٩	٠,٧٩	Strongly Disagree

TABLE IV: ANALYSIS OF THE RESPONSES ON THE SCALE OF THE STUDENTS' ATTITUDE TOWARDS THE PROPOSED VIRTUAL LABORATORY

Sr.	Paragraph		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Arithmetic average	Standard deviation	Attitude	Order
١	I feel I can acquire textile chemistry course skills with modern methods.	No.	٤	٥	١	٠	٠	٤,٣٠	٠,٦٧٥	Strongly Agree	٣
		%	٤٠	٥٠	١٠	٠	٠				
٢	The Virtual Textile Chemistry Lab makes it easy to learn Textile Chemistry course skills	No.	٥	٣	٢	٠	٠	٤,٣٠	٠,٨٢٣	Strongly Agree	٤
		%	٥٠	٣٠	٢٠	٠	٠				
٣	I prefer to learn Textile Chemistry course with the help of Virtual Textile Chemistry Lab	No.	٢	٢	٤	٢	٠	٣,٤٠	١,٠٧٥	Agree	١١
		%	٢٠	٢٠	٤٠	٢٠	٠				
٤	The virtual textile chemistry lab helped me learn the practical experiments of the textile chemistry course	No.	٤	٥	١	٠	٠	٤,٣٠	٠,٦٧٥	Strongly Agree	٣
		%	٤٠	٥٠	١٠	٠	٠				
٥	I feel anxious and apprehensive when I use the Virtual Textile Chemistry Lab	No.	٠	٣	٢	١	٤	٣,٦٠	١,٣٥٠	Disagree	١٠
		%	٠	٣٠	٢٠	١٠	٤٠				

٦	I think learning with the Virtual Textile Chemistry Lab is effective	No.	٣	٤	٢	١	٠	٣,٩٠	٠,٩٩٤	Agree	٩
		%	٣٠	٤٠	٢٠	١٠	٠				
٧	I think learning using the Virtual Textile Chemistry Lab is a modern method	No.	٧	٣	٠	٠	٠	٤,٧٠	٠,٤٨٣	Strongly Agree	١
		%	٧٠	٣٠	٠	٠	٠				
٨	Using the Virtual Textile Chemistry Lab enhanced my understanding of practical experiments	No.	٤	٤	٢	٠	٠	٤,٢٠	٠,٧٨٩	Strongly Agree	٥
		%	٤٠	٤٠	٢٠	٠	٠				
٩	I get bored when doing practical experiments in the virtual lab	No.	٠	١	١	٦	٢	٣,٩٠	٠,٨٧٦	Disagree	٨
		%	٠	١٠	١٠	٦٠	٢٠				
١٠	I enjoy applying practical experiments in the Virtual Textile Chemistry Lab	No.	٦	٤	٠	٠	٠	٤,٦٠	٠,٥١٦	Strongly Agree	٢
		%	٦٠	٤٠	٠	٠	٠				
١١	I think that learning with the Virtual Textile Chemistry Lab is attractive and interesting	No.	٦	٤	٠	٠	٠	٤,٦٠	٠,٥١٦	Strongly Agree	٢
		%	٦٠	٤٠	٠	٠	٠				
١٢	It is easy to use the Virtual Textile Chemistry Lab	No.	٥	١	٤	٠	٠	٤,١٠	٠,٩٩٤	Agree	٧
		%	٥٠	١٠	٤٠	٠	٠				
١٣	I was annoyed when I used the Virtual Textile Chemistry Lab	No.	٠	٤	١	٢	٣	٣,٤٠	١,٣٥٠	Disagree	١٢
		%	٠	٤٠	١٠	٢٠	٣٠				
١٤	I was pleased that I mastered the required skills because experiments could be repeated in the Virtual Textile Chemistry Lab without restrictions.	No.	٧	٣	٠	٠	٠	٤,٧٠	٠,٤٨٣	Strongly Agree	١
		%	٧٠	٣٠	٠	٠	٠				
١٥	I felt safe using the Virtual Textile Chemistry Lab	No.	٥	٣	١	١	٠	٤,٢٠	١,٠٣٣	Strongly Agree	٦
		%	٥٠	٣٠	١٠	١٠	٠				
١٦	I enjoyed learning Textile Chemistry course skills in general using the virtual lab	No.	٧	٣	٠	٠	٠	٤,٧٠	٠,٤٨٣	Strongly Agree	١
		%	٧٠	٣٠	٠	٠	٠				
The weighted average of the questionnaire as a whole								٤,١٨١٢		Agree	
The standard deviation of the questionnaire as a whole								٠,٤٩٢٥٢			

Table (IV) shows that there is a positive effect of the proposed virtual laboratory experiment on the students with a mean of (4.181) and a standard deviation of (0.495).

This result is further supported by the observation method using the observation card while the students experimented with the proposed virtual laboratory through observing how far they controlled the tools and how they tried to understand their feelings while performing the experiments in the proposed virtual laboratory.

Table (V) below shows the analysis of the observation cards by calculating the frequencies and percentages for each statement.

TABLE V: ANALYSIS OF THE OBSERVATION CARDS

Sr.	statement		Always	Often	Sometimes	Rarely	Never
١	The student easily controlled the tools	No. %	٧ ٧٠	٢ ٢٠	١ ١٠		
٢	The student was able to wear the virtual reality glasses	No. %	١٠ ١٠٠				
٣	The student felt dizzy when wearing the virtual reality glasses	No. %		٥ ٥٠	٣ ٣٠	١ ١٠	١ ١٠
٤	The student felt fear when wearing the virtual reality glasses	No. %					١٠ ١٠٠
٥	The student picked up the piece of fabric easily	No. %	٩ ٩٠	١ ١٠			
٦	The student read the written description	No. %	١٠ ١٠٠				
٧	The student moved easily from one experiment to another	No. %	٨ ٨٠	٢ ٢٠			
٨	The student easily accomplished what was required	No. %	٦ ٦٠	٣ ٣٠	١ ١٠		
٩	The student showed enthusiasm for using the virtual laboratory	No. %		٢ ٢٠	٥ ٥٠	٣ ٣٠	
١٠	The student repeated the experiment more than once to complete it	No. %	١ ١٠		٢ ٢٠	٣ ٣٠	٤ ٤٠
١١	The student showed a desire to know more	No. %		٢ ٢٠	١ ١٠	٥ ٥٠	٢ ٢٠

The previous table shows that the students' reactions during the experiments were generally positive. Therefore, it can be claimed that it is easy for the students to handle the virtual reality glasses in terms of wearing and using them to read the written description in the experiments. The students were also able to accomplish what was required of them with ease, such as controlling the tools, moving from one experiment to another, and picking up the fabric pieces. In addition, they did not feel fear when wearing the virtual reality glasses because of their enthusiasm to perform the experiment, although most of them felt a little dizzy when they first wore the glasses. It is also noted that the students mastered the experiments from the first attempt, as it was rare for the students to repeat any experiment. Despite the students' enthusiasm and appreciation for this experience, most of them weren't enthusiastic to learn more about the virtual lab.

V. DISCUSSION

The results of the study prove the validity of the first hypothesis, which states that "there are statistically significant differences between the mean scores of the students for (pre- and post-) achievement test in favor of the post-test". This is consistent with previous studies that maintain that the use of the virtual laboratory leads to an increase in students' academic achievement, positively affects their learning of various scientific subjects [11], [37], [38C], and it causes a significant change in their understanding of the scientific subject [19], [39]. The results also concur with the studies that used virtual reality and concluded that it improves the quality of education, increases student motivation, and boosts the cognitive level and skill performance of students [5], [40], [42]. However, the results disagree with another study [25], which finds that learning in virtual reality may distract and add burden to the learner, and therefore this may reduce opportunities to achieve learning outcomes.

The results also prove the validity of the second hypothesis, which states that “Students tend to be positively oriented towards learning the skills of identifying the type of fibers through chemical methods using the proposed virtual laboratory”. This agrees with many previous studies that proved that students have positive attitudes towards learning through the virtual laboratory [21], [37], and that the use of the virtual laboratory has a positive impact on the students' attitude towards the scientific course [11]. One of the studies [43] tended to determine the motivation of high school students to perform chemistry experiments in virtual reality through answering a questionnaire to determine the different dimensions of both internal and external motivations. The results of the questionnaire showed that students' opinions about using virtual reality were positive and it recommends using this technique in other topics.

Although the study proved that the use of virtual laboratories increases the students’ educational achievement, it should not be completely relied upon. Instead, it can be used as a support for the traditional laboratory such as carrying out experiments that are difficult to carry out in a traditional laboratory, or rather it may be used when there is a lack of materials or equipment necessary for the experiments. It may also be used in universities that lack traditional laboratories. The researchers came to this recommendation based on the difficulties they faced during the design of the proposed virtual laboratory, such as their inability to accurately explain the properties of materials when designing experiments because virtual reality depicts the material in 3D without precision in details. In addition, difficulties include the inability of the students to touch the materials during the experiments, which is seen as a shortcoming in the students' knowledge of the textile materials, and their inability to smell the odor in the burning experiment. This agrees with the conclusions of several other studies [10], [18], [21], [27], [28], [31] as they maintained that it is possible to use the virtual laboratory as a supplement to the traditional laboratory due to its similar effectiveness to the traditional laboratory. While another study [24] also aimed to develop a virtual laboratory to complement the traditional laboratory, one of the most important recommendations of another study [32] was the possibility of using virtual laboratory software as a support tool in traditional laboratories.

VI. Conclusion and Future Studies

E-learning has recently received much attention and interest as it has become available in various educational institutions. This is evident in the publication of a wide range of studies and research on e-learning and distance education initiatives. Educational institutions play a major role in developing this field and measuring its effectiveness in educational performance.

This research sought to shed light on the importance of using virtual reality technology to learn the skills of identifying the type of fibers using chemical methods by designing and setting up a virtual laboratory and subsequently measuring its effectiveness. The study was conducted on the 10 students enrolled in the Textile Chemistry course by applying the achievement test to the research sample before and after using the virtual laboratory. It is found that the average score for the post-test is higher than the average score for the pre-test. The results indicated the positive effect of the proposed virtual laboratory on the students in learning the skill of identifying the type of fibers by chemical methods. At the end of the study, a students' attitude scale was distributed to the students to measure their attitude towards learning using the proposed virtual laboratory. The results indicated that the students have positive attitudes towards learning using the proposed virtual laboratory.

Considering the previous results, virtual laboratories can be used as a support for traditional laboratories in studying Textile Chemistry courses. Furthermore, the virtual fabric chemistry lab may also be applied using other objectives and experiments for the course. This technique can also be used in other courses in the clothing and textile major. It is also possible to use the experiments conducted in this study in virtual laboratories online and duly publish them on websites.

For future studies, there is a need to probe the necessity of employing virtual reality technology in various education fields, and to expand in employing virtual laboratories in teaching various science courses.

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فاعلية مختبر افتراضي لتنمية مهارات تحديد أنواع الشعيرات النسيجية باستخدام الطرق الكيميائية

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المستخلص. يعد الواقع الافتراضي أحد ابتكارات تكنولوجيا المعلومات وهو عبارة عن بيئة ثلاثية الأبعاد تحاكي الواقع تم إنشاؤها لتقديم المساعدة للأفراد للتعامل مع المعلومات وإدراكها بصريًا بسهولة أكبر. أُستخدم الواقع الافتراضي في العديد من التخصصات ومن الملاحظ ندرة استخدامه في مجال كيمياء النسيج على الرغم من احتياج بعض الجامعات لتوفير بديل عن المختبر التقليدي. هدفت هذه الدراسة إلى تصميم مختبر افتراضي مقترح لإكساب الطالبات مهارات تحديد أنواع الشعيرات النسيجية باستخدام الطرق الكيميائية، وقياس فاعليته وذلك لمواكبة التطور التكنولوجي السريع وتوظيفها في العملية التعليمية. اتبعت الدراسة المنهج التجريبي حيث تم استخدام الاختبار التحصيلي ومقياس الاتجاه للتحقق من صحة فرضيات الدراسة بعد تطبيقها على عينة قصدية ١٠ طالبات مقرر كيمياء النسيج – قسم الملابس والنسيج – جامعة الملك عبد العزيز. توصلت الدراسة إلى أنه توجد فروق ذات دلالة إحصائية عند مستوى دلالة (٠,٠٥) بين متوسطي درجات الطالبات في الاختبار التحصيلي (القبلي – البعدي) لصالح الاختبار البعدي، وفقاً لنتيجة اختبار (ت) للعينات المترابطة. ويوجد اتجاه إيجابي لدى الطالبات عينة البحث نحو التعلم باستخدام المختبر الافتراضي المقترح. وتوصي الباحثة في استخدام المختبرات الافتراضية كوسيلة دعم للمختبرات التقليدية في تدريس مهارات تحديد أنواع الشعيرات النسيجية باستخدام الطرق الكيميائية.

الكلمات المفتاحية. مختبر افتراضي، نسيج، شعيرات نسيجية، تحديد، كيمياء النسيج